Original Article

Comparison of Effects of Guidewire-Assisted and Direct Arterial Puncture Technique on Success Rate of Radial Artery Cannulation by Inexperienced Trainees

Worapot Apinyachon MD[1], Natthaporn Boonyakad MD[1], Inthuon Sangasilpa MD[1], Phisut Lavanrattanakul MD[1]

[1] Department of Anesthesiology, Faculty of Medicine Ramathibodi Hospital, Mahidol University, Bangkok, Thailand

Background: The radial artery is the preferred site for arterial cannulation. However, cannulation is sometimes difficult and requires multiple attempts, especially by inexperienced trainees. Guidewire-assisted cannulation (GW) is a simple and effective technique, but this maneuver requires practice.

Objective: To compare the effects of a direct arterial puncture (DP) and a GW technique on the success rate of radial artery cannulation by inexperienced trainees.

Materials and Methods: The present study was a prospective cohort study. Sixty patients with the American Society of Anesthesiologists physical status of I to III that underwent elective surgery requiring radial artery cannulation were included in this study. In the GW group, thirty radial artery cannulations were performed by inexperienced surgical residents using a GW technique. In the DP group, 30 patients underwent radial artery cannulation with a DP technique by inexperienced anesthesiology residents. The primary outcome was the success rate of radial artery cannulation.

Results: There were no differences in the baseline blood pressure or comorbidities between the two groups. Overall, the success rate of radial artery cannulation in the GW and DP groups were 90% and 50%, respectively (p=0.001). The success rate of first-attempt cannulation in the GW and DP group were 66.7% and 26.7%, respectively (p=0.002). The total procedural performance time was significantly shorter in the GW than DP group.

Conclusion: The GW technique achieved a higher success rate than the DP technique when performed by inexperienced trainees.

Keywords: Blood Pressure; Catheterization peripheral/methods; Catheterization peripheral/adverse effects; Internship and residency; Radial artery; Training support

Received 21 November 2021 | Revised 17 January 2022 | Accepted 17 January 2022

J Med Assoc Thai 2022;105(2):121-6

Website: http://www.jmatonline.com

Invasive blood pressure monitoring is commonly used in patients requiring continuous blood pressure measurement or frequent blood sampling[1]. The radial artery is the most used artery for the present study purpose because of its superficial location and fewer complications compared with other sites[2]. Catheter placement can be performed using various techniques, including direct arterial puncture (DP) or palpation as well as guidewire-assisted or ultrasound-guided arterial line placement[3]. In training programs, radial artery cannulation is a compulsory procedure for anesthesiology residents. Inevitably, the risks and practice requirements of various procedures are topics of concern in any academic training center.

The authors used a DP technique for radial artery cannulation at the authors' residency training program. However, insertion of the radial artery catheter is sometimes difficult and requires multiple attempts, especially for inexperienced trainees. This may lead to insertion failure and insertion-related complications. Unsurprisingly, more experienced trainees have higher cannulation success rates. However, the development of training methods for practicing radial artery cannulation, such as pre-procedural simulator training or video demonstrations, can significantly improve the success rate for inexperienced trainees[4]. The most fundamental technique for radial artery cannulation is DP, which is performed without any assisting devices and has a learning curve. Therefore,

Correspondence to:

Lavanrattanakul P.

Department of Anesthesiology, Faculty of Medicine Ramathibodi Hospital, Mahidol University, 270 Rama VI Road, Ratchathewi, Bangkok 10400, Thailand.

Phone: +66-2-2011513

Email: kathualavan@gmail.com

How to cite this article:

Apinyachon W, Boonyakad N, Sangasilpa I, Lavanrattanakul P. Comparison of Effects of Guidewire-Assisted and Direct Arterial Puncture Technique on Success Rate of Radial Artery Cannulation by Inexperienced Trainees. J Med Assoc Thai 2022;105:121-6.

DOI: 10.35755/jmedassocthai.2022.02.13265

its failure rate remains high among inexperienced practitioners and even skilled anesthesiologists[4,5]. The use of a guidewire or the Seldinger technique to aid radial artery cannulation is a reliable method that can achieve a high success rate[6,7]. However, training and practice are required for practitioners who are unfamiliar with the technique or those having less experience[8].

The main objective of the present study was to compare the effects of DP and a guidewire-assisted cannulation (GW) technique on the success rate of radial artery cannulation by inexperienced trainees.

Materials and Methods

The present study was a prospective cohort study that was approved by the Institutional Ethics Committee of Mahidol University (MURA 2018/273, protocol ID: 046125, approval date: September 10, 2018), and was registered on the Thai Clinical Trials Registry (identifier: TCTR20200601004). All patients signed a written consent form before their participation in the present study conducted between October 2018 and September 2019 at Ramathibodi Hospital, Mahidol University. The reporting in the present manuscript followed the recommendations in the STROBE guideline.

All patients underwent elective surgery under general anesthesia, had the American Society of Anesthesiologists (ASA) physical status of I to III, were older than 18 years, and required radial artery cannulation for intraoperative monitoring. The authors excluded patients requiring insertion of an arterial line before induction of anesthesia who had previously undergone radial artery cannulation during the same hospital admission, had unstable vital signs, or had peripheral vascular disease. The study collected the data from two periods. The DP group was conducted when the new first-year anesthesiology residency trainees started working at the operating room after the orientation program. The GW group was conducted in surgical residency trainees rotated into selective period in the anesthesiology department.

In the DP group, the cannulation procedures were performed by first-year anesthesiology residents who had performed either zero or one radial artery cannulation. They had attended simulator training of radial artery cannulation by DP on a manikin-based training and watched a video demonstrating this cannulation technique on the orientation day of the training program. In the GW group, radial artery cannulation was performed by inexperienced surgical residents who had only performed arterial blood gas sampling and had never performed radial artery cannulation. The attending anesthesiologist showed the video clip demonstrating steps of GW technique to surgical residents on the morning of procedure. After watching video that was approximately seven minutes, the surgical residents were able to ask any question before the procedure. The nurse anesthetists prepared the radial artery cannulation equipment for the trainees.

Both techniques started with the patient's arm secured on an arm board, the wrist extended, and the fingers fixed. In the DP group, after cleaning the cannulation site with antiseptic solution, the DP began with manual palpation to identify the site of maximal pulsation. After the point of puncture had been identified, a 20-gauge fluorinated ethylene propylene polymer catheter (Jelco; Smiths Medical, Minneapolis, MN, USA) was used to puncture the skin at an angle of 30° to 45°. After arterial blood was seen in the hub of the catheter, the catheter was dropped to 5° to 10° and slightly advanced to ensure cannulation of the artery. Finally, the needle was held in place while the catheter was advanced into the radial artery. In the GW group, after arterial blood was seen in the hub of catheter, the arterial catheter was advanced through the posterior wall of the radial artery. The needle was removed, and the catheter withdrawn until arterial blood pulsation was seen. Half of the guidewire (0.018" × 9¾") (Arrow; Teleflex, Wayne, PA, USA) was inserted, and the arterial cannula was then advanced into the radial artery.

Intraoperatively, all patients were maintained under general anesthesia with an endotracheal tube. After induction of anesthesia, radial artery cannulation was performed. All residents performed their radial artery cannulation technique. When the residents had completed their procedure, the catheter was connected to the pressure transducer to obtain the arterial waveform.

Successful cannulation of the radial artery was defined as the appearance of an arterial waveform on the monitor after connection to the transducer. The insertion time was measured from the first needle puncture of the patient's skin to placement of the catheter into the radial artery. The number of attempts was counted as the number of needle advances through a skin puncture until the patient's blood was seen in the hub. Failure of cannulation was defined as no achievement of radial artery cannulation within two attempts or a procedural time of more than 15 minutes. In cases of failure, the arterial cannulation was performed by the attending anesthesiologist.

Table 1. Patient characteristics

	Guidewire-assisted group (n=30)	Direct arterial puncture group (n=30)	p-value
Age (years); mean±SD	57.3±14.2	58.7±13.2	0.693
BMI (kg/m^2); mean±SD	22.4±3.2	23.3±4.4	0.401
Sex: female; n (%)	11 (36.7)	17 (56.7)	0.121
ASA physical status; n (%)			0.093
I	3 (10.0)	3 (10.0)	
II	18 (60.0)	10 (33.3)	
III	9 (30.0)	17 (56.7)	
Comorbidities; n (%)			
Diabetes mellitus	7 (23.3)	6 (20.0)	0.754
Hypertension	16 (53.3)	16 (53.3)	1.000
Coronary artery disease	1 (3.3)	2 (6.7)	0.557
End-stage renal disease	0 (0.0)	2 6.7)	0.150
Before arterial catheterisation; mean±SD			
Systolic blood pressure (mmHg)	116.7 ± 18.1	123.3 ± 24.5	0.262
Diastolic blood pressure (mmHg)	66.8 ± 10.6	70.9 ± 10.9	0.148
Pulse rate (beats/minute)	74.9 ± 16.7	79.4 ± 13.0	0.243

SD=standard deviation; BMI=body mass index; ASA=American Society of Anesthesiologists

The number of attempts and the cannulation time were recorded by the nurse anesthetists who were not involved in the present study. The record of procedural time was stopped when the arterial waveform was seen on the monitor or failure of cannulation. Other collected data were the patients' characteristics, ASA physical status, underlying diseases, vital signs before cannulation, and local hematoma formation after cannulation.

Statistical analysis

The sample size was calculated by the success rate of the direct puncture and guidewire-assisted techniques in the previous study[9], which were 70% and 93%, respectively, with a type I error of 0.05 and power of 0.8. The result indicated that 29 patients were required in each group. Therefore, 60 patients were enrolled into the present study.

Statistical analysis was performed using IBM SPSS Statistics, version 20.0 (IBM Corp., Armonk, NY, USA). Continuous data were presented as mean ± standard deviation or median (interquartile range). Categorical data were presented as number (percentage). The chi-square test or Fisher's exact test was performed to compare categorical variables, and the Student's t-test or the Mann-Whitney U test was performed to compare continuous variables in each group. Kaplan-Meier curves of the cumulative success of cannulation and the procedural performance time were plotted. The log-rank test was performed for statistical comparison of cumulative success between the two groups. A p-value of less than 0.05 was considered statistically significant.

Results

The DP group comprised of 15 first-year anesthesiology residency trainees, and the GW group comprised of 30 surgical residency trainees.

Sixty patients participated in the present study and were divided into 30 for the GW group and 30 for the DP group. Table 1 shows the patients' demographic data of the two groups. There were no significant differences in age, body mass index, or comorbidities. Immediately before catheterization, there were no significant differences in the baseline hemodynamic parameters between the two groups.

The overall success rate of radial artery cannulation was 27 of 30 (90.0%, 95% CI 73.5 to 97.9) patients in the GW group, and 15 of 30 (50.0%, 95% CI 31.3 to 68.7) patients in the DP group (p=0.001). The first-attempt cannulation success rate was significantly higher in the GW group as compared to the DP group (Table 2).

The Kaplan-Meier curve of successful insertion of the arterial line by the study groups are shown in Figure 1. The log-rank test showed a statistically significant difference between the two groups (p=0.002). In successful cannulations, the mean time was not significantly different between the two groups. However, the total procedural performance time was significantly shorter in the GW than DP group. Successful cannulation times in both groups were less

Table 2. Success rate and cannulation time

	Guidewire-assisted group (n=30)	Direct arterial puncture group (n=30)	p-value
Overall success rate; n (%)	27 (90.0)	15 (50.0)	0.001*
Number of attempts; n (%)			0.002*
First-attempt success rate	20 (66.7)	8 (26.7)	
Second-attempt success rate	7 (23.3)	7 (23.3)	
Time to successful cannulation; mean±SD	2.36±1.36	2.46±1.44	0.892
Procedural performance time (minute); median (IQR)	2.24 (1.39 to 3.28)	4.47 (2.06 to 8.05)	0.033*

SD=standard deviation; IQR=interquartile range

* Represented a p<0.05 which is statistically significant

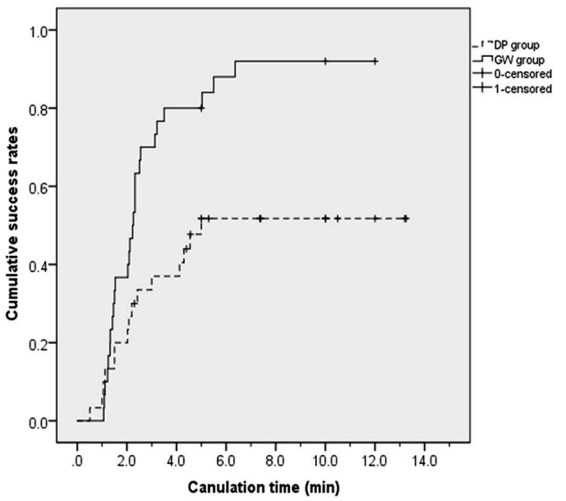

Figure 1. Kaplan-Meier curve of cumulative success rate.

DP=direct arterial puncture; GW=guidewire-assisted cannulation

than five minutes. Among successful cannulations, 24 (88.9%) participants in the GW group spent less than five minutes to achieve successful radial artery cannulation, whereas 15 (100%) participants in the DP group spent less than 5 minutes to achieve successful cannulation.

In terms of complications, a hematoma was found in seven of 30 (23.3%) patients in the GW group, and in 11 of 30 (36.6%) patients in the DP group. There was no significant difference between the two groups.

Discussion

In the present study, the guidewire-assisted radial artery cannulation technique increased the overall success rate among inexperienced trainees from 50% to 90%. Additionally, the first-attempt cannulation success rate was significantly higher in the guidewire-assisted technique than in DP.

The process of cannulation requires delicate and fine-tuned hand movements. Previous studies have shown low cannulation success rates in trainees with minimal or no experience ranging from 34.0% to 38.6%[5,10]. Theoretically, learning how to perform radial artery cannulation is a psychomotor skill that requires a certain amount of practice and supervisor feedback to achieve success and gain experience. Thus, the previous studies have shown that radial artery cannulation with the direct puncture technique performed by experienced clinicians has higher success rates ranging from 56.4% to 82.0% depending on factors such as the vessel size, catheter type, and performer's experience[11,12]. During a training program, every trainee must practice to gain experience with radial artery cannulation. However, this practice may involve either multiple cannulation attempts or failure, leading to procedure-related complications such as hematomas, vasospasm, infection, or vessel thrombosis[13].

For inexperienced trainees, the determining factors of successful radial artery cannulation are identification of the appropriate puncture site of the artery and railroading the catheter into the artery. The inexperienced trainees might not be confident with the artery palpation technique and may encountered difficulties in identification of the radial artery puncture site. This may result in misalignment of the puncture point over the radial artery. The diameter of radial artery is small at the wrist with an average diameter of 2.25 to 2.32 mm[14,15]. Moreover, the outer diameter of a 20-G catheter, which is the standard size for radial artery cannulation in adults, is 1.1 mm. Consequently, this procedure is often difficult for inexperienced trainees. Therefore, new techniques and various tools have been developed to facilitate easier and faster radial artery cannulation. Ultrasonography is useful for visualization of the vessel underneath the body surface for visual projection instead of palpation. Previous studies have used ultrasound guidance to locate the position of the radial artery. However, Zhefeng et al[16] found no benefit of ultrasound-guided

puncture. They showed that the use of traditional real-time ultrasonic localization of the artery by inexperienced trainees produced a cannulation success rate of only 34.2%. Another study involving senior anesthesiology residents who performed ultrasound-guided versus landmark-palpation radial artery cannulation showed no significant difference in the success rate between the two techniques at 78% versus 82%, respectively[12]. The authors stated that the lack of a significant difference could be explained by the learning curve of ultrasound-guided cannulation, which was a state-of-the-art and unfamiliar technique. In contrast, a recent study showed that ultrasound guidance increased the first-attempt success rate but not the overall cannulation success rate when compared with digital palpation[3]. As mentioned above, the ultrasound-guided technique facilitates precise visualization of the artery location. However, the success rate of radial artery cannulation in inexperienced trainees with ultrasound guidance was low and unsatisfactory. The present study involved participants who were inexperienced in radial artery cannulation and had been trained only by watching media or practicing on manikins. Nevertheless, the present study showed that the effectiveness of watching short video media that demonstrate the steps of procedure in group of surgical residents would be sufficient for the performers. The success rate was higher in the guidewire-assisted group, which may be explained by the last step of radial artery cannulation, which is the advancement of the catheter into the vessel. Beards et al[9] noted that failure to cannulate the artery using the direct puncture technique commonly resulted from an inability to successfully advance the catheter even though the needle appeared to be within the artery. Additionally, studies involving pediatric patients showed that advancing the catheter after arterial wall penetration was more difficult than localization of the artery[17,18]. Mangar et al[6] study suggested that the causes of failed cannulation were tangential orientation of the catheter in relation to the position of artery or tortuosity of the vessel. In such cases, a guidewire can facilitate advancement of the catheter through the skin and subcutaneous tissue and into the blood vessel.

In the present study, the overall procedural performance time was shorter in the guidewire-assisted group. The present study protocol allowed the participant trainees to perform two radial artery cannulation procedures within 15 minutes. In this study, successful cannulations, either guidewire-assisted or by the direct puncture technique, were able to succeed within the first five minutes. Because the authors' facility is a teaching hospital, the instructors must balance the need for the trainees to practice cannulation skills and the risk of injury to patients or a long procedure time. Therefore, the practice time for radial artery cannulation by inexperienced trainees was expected to be 5 to 10 minutes. Even in a study comparing ultrasound-guided radial artery cannulation, which is a newer technique, versus the direct puncture technique, successful cannulations required less than five minutes, even at various levels of residency training[5].

The present study has limitations. Inevitably, there was the effect of first-time experience on arterial cannulation to the second performance in anesthesiology residents. The present study could not know or assess the individual operators' learning experience from the prior cannulation. Secondly, the present study did not evaluate the comprehensive assessment after the manikin- based training and watching video media in anesthesiology residents. The lack of understanding of the task affects the acquisition of procedural skills[19]. Lastly, the authors did not have a simulator training of radial artery cannulation in surgical residents. The success rate of cannulation might be altered in performers who have an effective procedural skill training.

Conclusion

Guidewire-assisted radial artery cannulation showed a significantly higher success rate and shorter procedural performance time. Guidewire-assisted radial artery cannulation has advantages over DP when performed by inexperienced trainees.

What is already known on this topic?

DP technique had high failure rate in inexperienced trainees. Guidewire-assisted radial cannulation technique when comparing to DP technique has higher success rate in critical or pediatric patients with experienced operators.

What this study adds?

The anesthesiology residents having previous training for DP technique in manikin showed the low success rate with this technique. The DP technique required repetitive practices to gain the success rate. To the authors' knowledge, no previous study reported the success rate of guidewire-assisted radial cannulation in inexperienced trainees. The most important finding is that this study reported the learning technique with VDO clip demonstrating

guidewire-assisted radial cannulation without prior simulation or manikin training for inexperienced surgical residents. It was a fast and effective method. Consequently, the higher success rate in surgical residents was observed. From the previous studies, the ultrasound-guided radial artery cannulation that directly visualize the position of radial artery did not increase the success rate of either inexperienced or experienced trainees. As a result, the guidewire-assisted should be the first choice for radial artery cannulation in every inexperienced operator.

Authors' contributions

WA processed data clearance, data analysis, data interpretation, and drafted the manuscript, NB participated in designing and coordinating the study, IS contributed to data collection, prepared the figures, and tables, and PL contributed to the study design and revised the manuscript. All authors read and approved the final manuscript.

Conflicts of interest

The authors declare no conflict of interest.

References

1. Esper SA, Pinsky MR. Arterial waveform analysis. Best Pract Res Clin Anaesthesiol 2014;28:363-80.
2. Brzezinski M, Luisetti T, London MJ. Radial artery cannulation: a comprehensive review of recent anatomic and physiologic investigations. Anesth Analg 2009;109:1763-81.
3. Bhattacharjee S, Maitra S, Baidya DK. Comparison between ultrasound guided technique and digital palpation technique for radial artery cannulation in adult patients: An updated meta-analysis of randomized controlled trials. J Clin Anesth 2018;47:54-9.
4. Nakayama Y, Inagaki Y, Nakajima Y, Sessler DI, Mukai N, Ogawa S, et al. A practical training program for peripheral radial artery catheterization in adult patients: A prospective, randomized controlled trial. Anesthesiology 2016;125:716-23.
5. Kiberenge RK, Ueda K, Rosauer B. Ultrasound-guided dynamic needle tip positioning technique versus palpation technique for radial arterial cannulation in adult surgical patients: A randomized controlled trial. Anesth Analg 2018;126:120-6.
6. Mangar D, Thrush DN, Connell GR, Downs JB. Direct or modified Seldinger guide wire-directed technique for arterial catheter insertion. Anesth Analg 1993;76:714-7.
7. Yildirim V, Ozal E, Cosar A, Bolcal C, Acikel CH, Kiliç S, et al. Direct versus guidewire-assisted pediatric radial artery cannulation technique. J Cardiothorac Vasc Anesth 2006;20:48-50.
8. Gronbeck C 3rd, Miller EL. Nonphysician placement of arterial catheters. Experience with 500 insertions. Chest 1993;104:1716-7.
9. Beards SC, Doedens L, Jackson A, Lipman J. A comparison of arterial lines and insertion techniques in critically ill patients. Anaesthesia 1994;49:968-73.
10. Li YH, Wang YQ, Zeng L, Chen W, Yang LY, Zhu QF, et al. Use of 1-ml hollow tube-assisted radial artery catheterization in clinical anesthesiology. Int J Clin Exp Med 2014;7:2740-3.
11. Peters C, Schwarz SK, Yarnold CH, Kojic K, Kojic S, Head SJ. Ultrasound guidance versus direct palpation for radial artery catheterization by expert operators: a randomized trial among Canadian cardiac anesthesiologists. Can J Anaesth 2015;62:1161-8.
12. Tangwiwat S, Pankla W, Rushatamukayanunt P, Waitayawinyu P, Soontrakom T, Jirakulsawat A. Comparing the success rate of radial artery cannulation under ultrasound guidance and palpation technique in adults. J Med Assoc Thai 2016;99:505-10.
13. Scheer B, Perel A, Pfeiffer UJ. Clinical review: complications and risk factors of peripheral arterial catheters used for haemodynamic monitoring in anaesthesia and intensive care medicine. Crit Care 2002;6:199-204.
14. Beniwal S, Bhargava K, Kausik SK. Size of distal radial and distal ulnar arteries in adults of southern Rajasthan and their implications for percutaneous coronary interventions. Indian Heart J 2014;66:506-9.
15. Ashraf T, Panhwar Z, Habib S, Memon MA, Shamsi F, Arif J. Size of radial and ulnar artery in local population. J Pak Med Assoc 2010;60:817-9.
16. Zhefeng Q, Luo C, Zhang L, Li X, He H, Chi P. Application of optimized ultrasonic localization system for radial artery puncture by intern doctors: A randomized trial. Med Sci Monit 2019;25:1566-71.
17. Cuper NJ, de Graaff JC, Hartman BJ, Verdaasdonk RM, Kalkman CJ. Difficult arterial cannulation in children: is a near-infrared vascular imaging system the answer? Br J Anaesth 2012;109:420-6.
18. Jang YE, Kim EH, Lee JH, Kim HS, Kim JT. Guidewire-assisted vs. direct radial arterial cannulation in neonates and infants: A randomised controlled trial. Eur J Anaesthesiol 2019;36:738-44.
19. Bould MD, Crabtree NA, Naik VN. Assessment of procedural skills in anaesthesia. Br J Anaesth 2009;103:472-83.